Contribution of DFIG wind turbines to Primary Frequency Control

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Abstract

In recent years, worldwide power systems are experiencing a steadily growth in wind power penetration. A common concern in the operation of such systems is related to the frequency stability. Modern variable speed wind turbines have a limited capacity in providing ancillary services, such as: fast-frequency response and primary frequency regulation. This thesis aims at developing a new methodology for the analysis of frequency dynamics in large-scale power systems with high level of wind energy share. Firstly, a simplified electromechanical model of a doubly fed induction generator (DFIG) based wind turbine has been proposed. In addition, a virtual inertia controller version of the optimized power point tracking method (OPPT) has been adapted for this kind of wind turbines. In this method, the maximum power point tracking curve (MPPT) is shifted to drive variations in the active power injection as a function of the grid frequency deviation, by exploiting the available inertial resources. The proposed methodology integrates the model in a primary frequency control scheme to assess the interaction with the rest of the plants in the power system.

I. DFIG-WT model

A simplified electromechanical model oriented to power-frequency studies has been developed. For validation, a MATLAB-Simulink detailed model has been used.

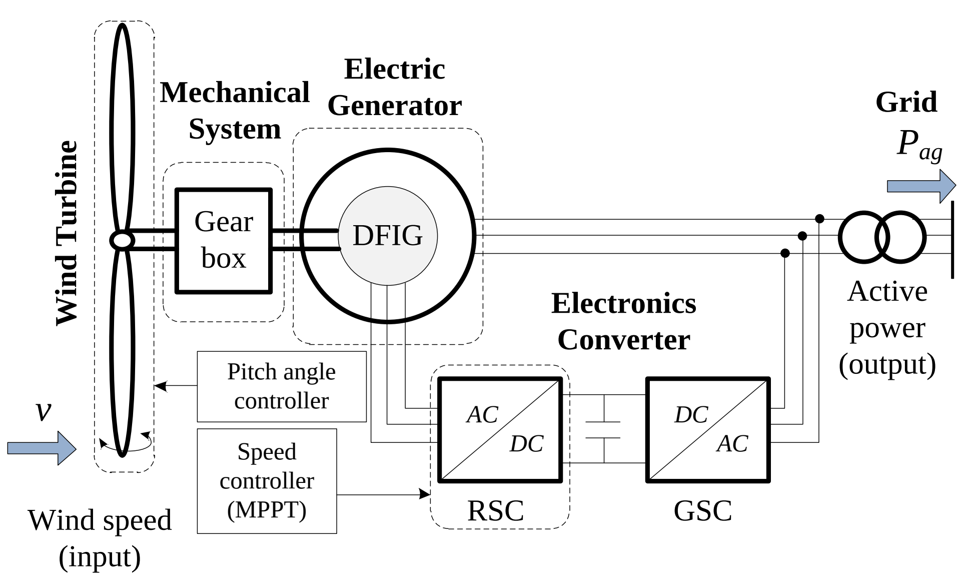


Fig. 1. DFIG-wind turbine general scheme.

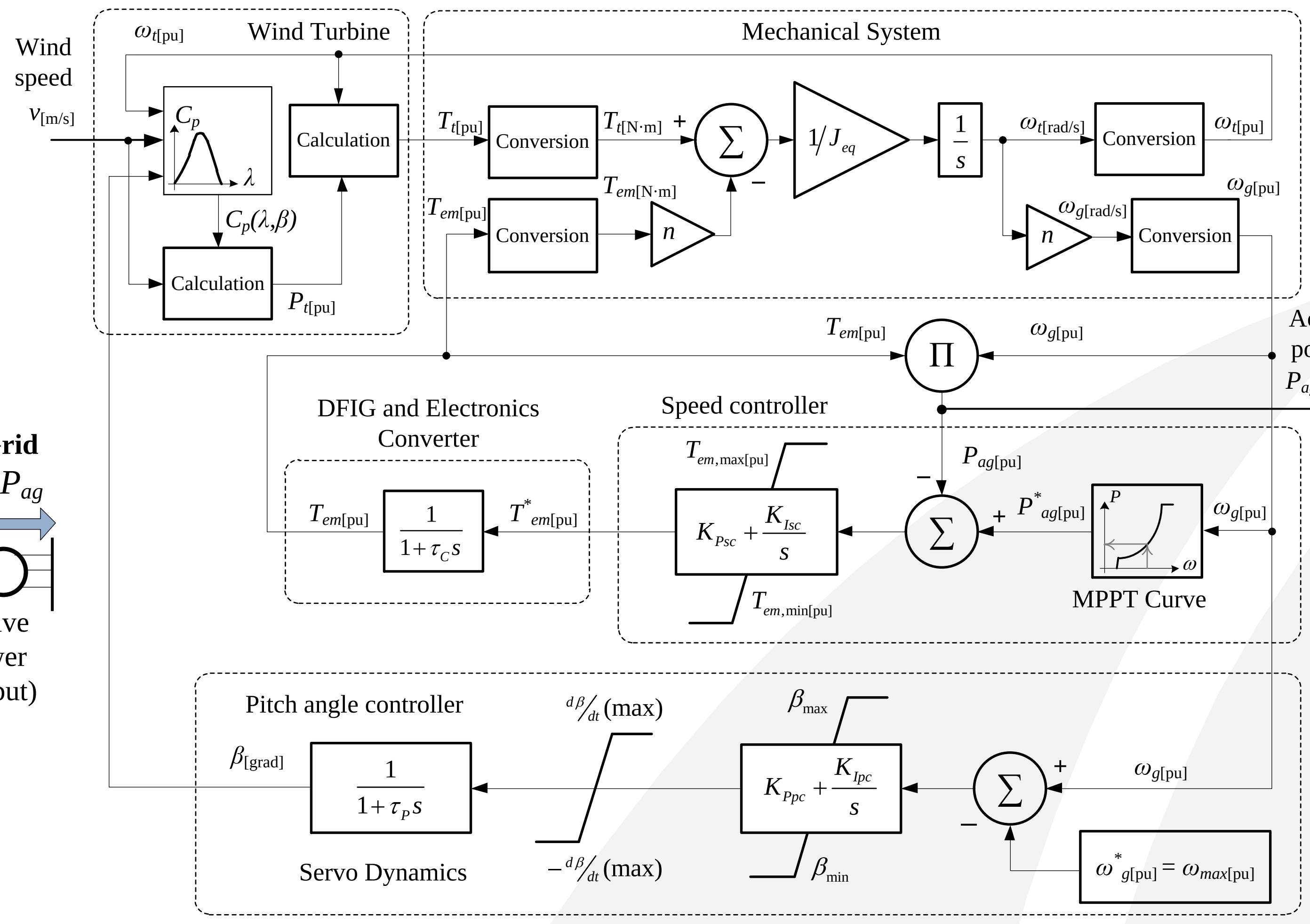


Fig. 2. Simplified electromechanical DFIG-wind turbine model.

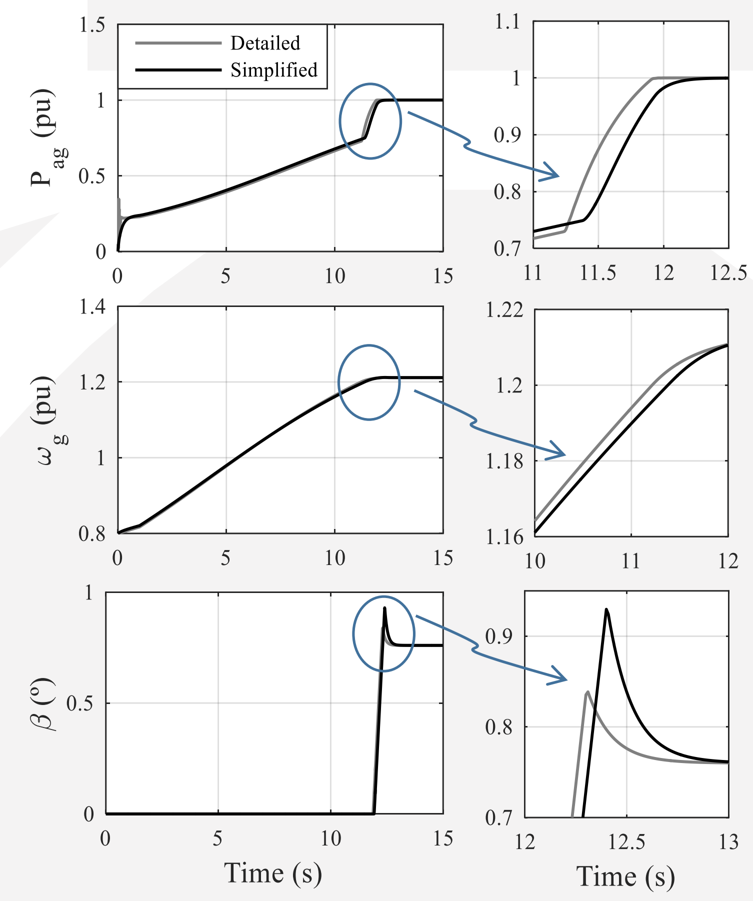


Fig. 3. Validation of the model.

II. Fast-frequency response scheme

A novel control strategy for performing fast-frequency response by a DFIG-WT has been adapted in the aforementioned model (Fig. 4). According to the OPPT method (Fig. 5), the DFIG-WT has to leave its optimal operation point (A) and move to (B) when an under-frequency (UF) event occurs. Then, its operation point will ride along the points B and C by means of shifting the MPPT curve to the left. After this frequency support, the DFIG-WT will recover its optimal pre-disturbance conditions (A). In case of an over-frequency event, the DFIG-WT will describe the path A→D→E→A.

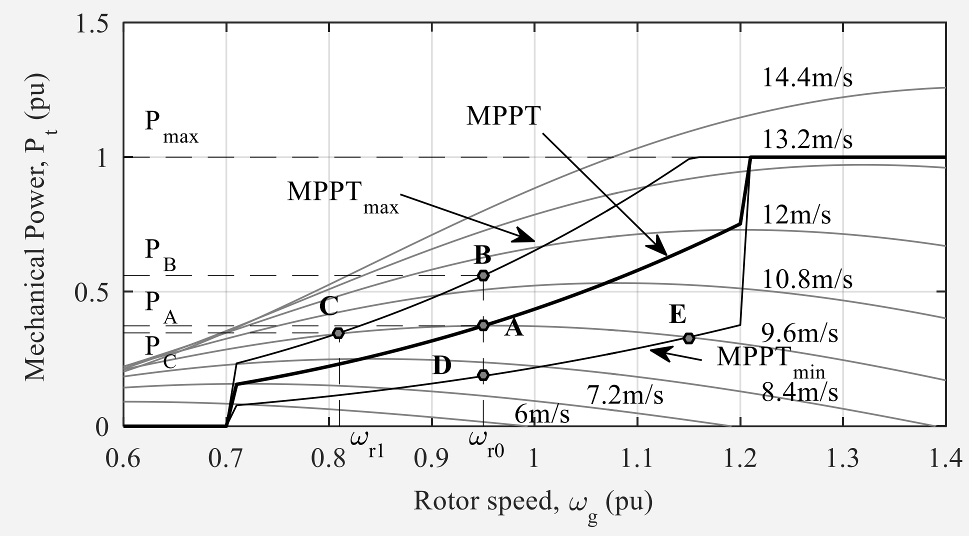


Fig. 5. Explanation of the OPPT method.

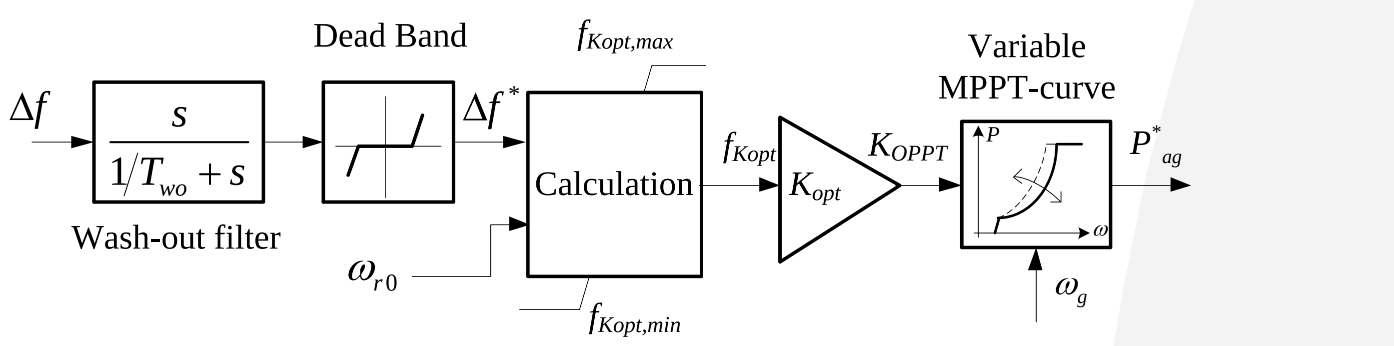
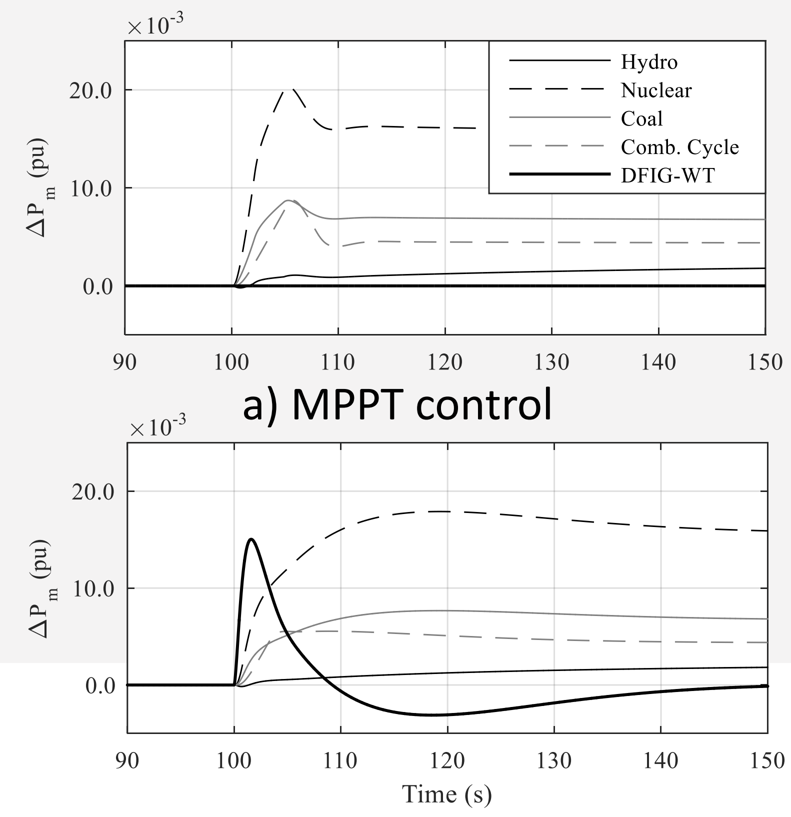


Fig. 4. Aggregated control scheme for implementing the OPPT method.

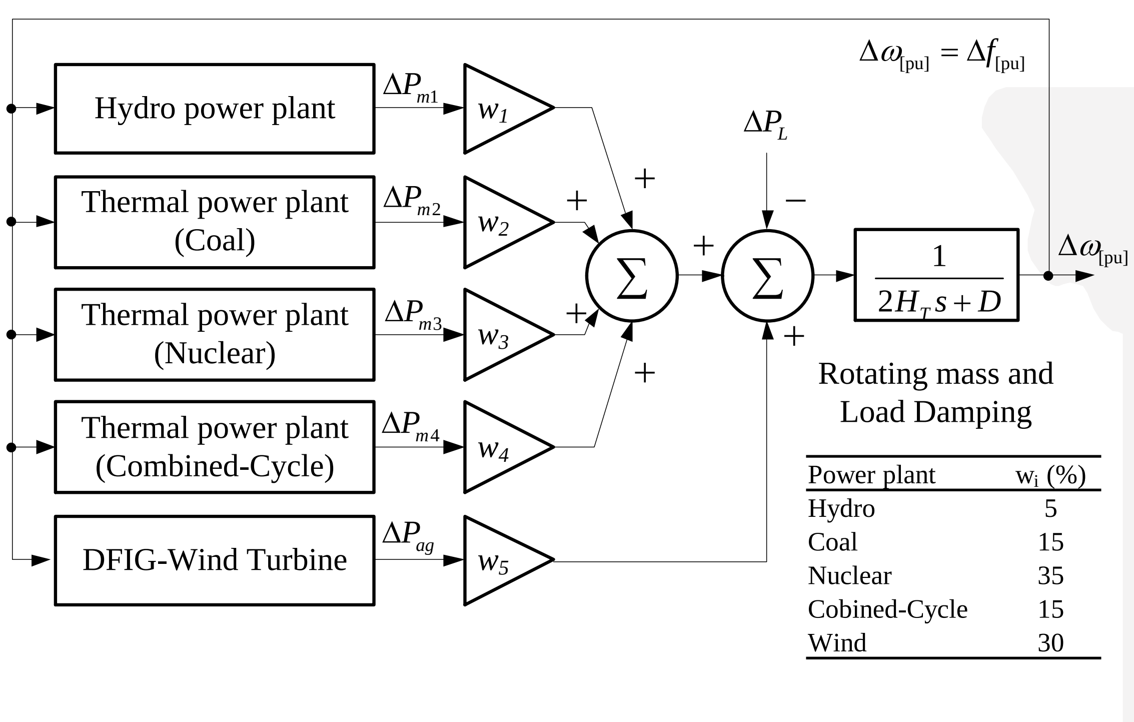
III. Simulation and results

The proposed DFIG-WT model has been incorporated into a traditional primary frequency control scheme for a single control area (Fig. 6). The behavior of certain variables of the DFIG-WT and the grid frequency dynamics during a load sudden increase is illustrated in Fig. 7. The primary frequency control actions provided by each power plant is presented in Fig. 8. Finally, Fig. 9 shows the reduction of the maximum instantaneous frequency deviation (MIFD) when the OPPT method is applied on a DFIG-WT as a function of the incoming wind speed.



b) OPPT control

Fig. 8. Primary frequency control provided by each power plant (UF-event).



Power plant	w_i (%)
Hydro	5
Coal	15
Nuclear	35
Cobined-Cycle	15
Wind	30

Fig. 6. Primary frequency control scheme.

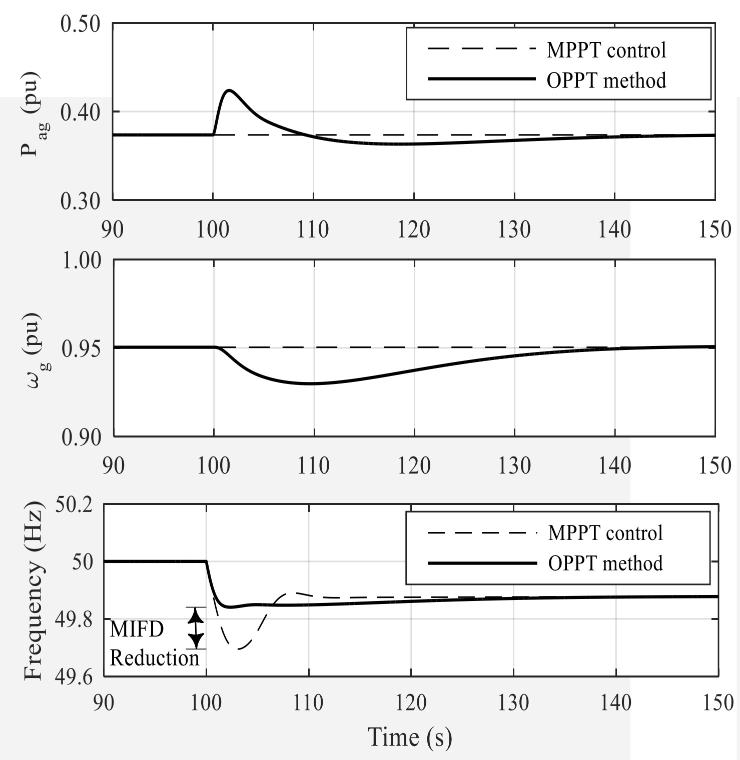


Fig. 7. Simulation results (v = 9.6 m/s).

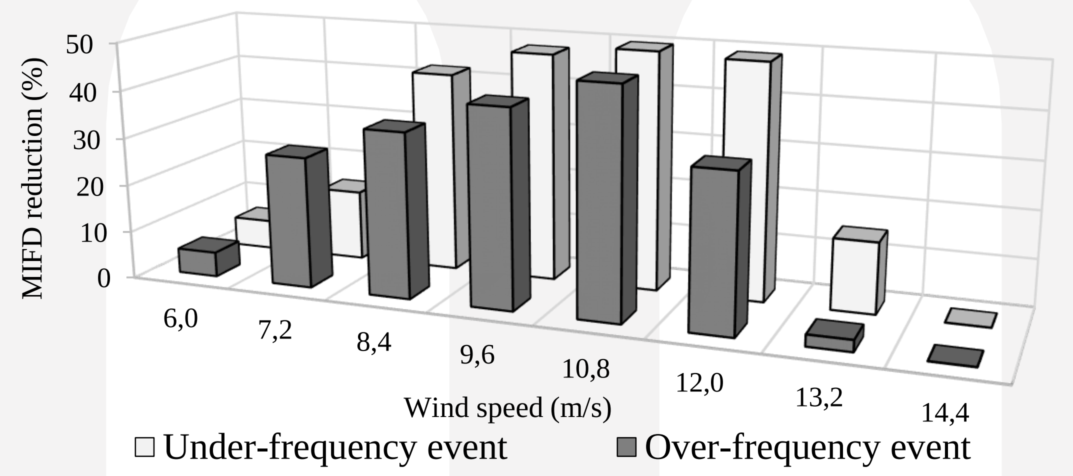


Fig. 9. Reduction of the MIFD vs. wind speed.